NASA TECHNICAL MEMORANDUM

NASA TM X-68062

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AN APPLICATION OF INTERACTIVE GRAPHICS TO NEUTRON SPECTROMETRY

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September 1972

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ABSTRACT

The use of interactive graphics is presented as an attractive method for performing multi-parameter data analysis of proton recoil distributions to determine neutron spectra. Interactive graphics allows the user to view results on-line as the program is running and to maintain maximum control over the path along which the calculation will proceed. Other advantages include less time to obtain results and freedom from handling paper tapes and IBM cards.

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SUMMARY

The use of interactive graphics is presented as an attractive method for performing on-line data analysis procedures. In particular, the use of such a graphics package is described for the multi-parameter data analysis involved in the determination of neutron spectra from proton recoil pulse height distributions. The computer code SOCONS, which performs on-line calculations on a PDP computer, is discussed. The interactive graphics features of SOCONS allow the user to view his results on-line as the program is running. The user also has maximum control over the path along which the calculation will proceed. Other advantages include less time to obtain results and freedom from handling paper tapes and IBM cards.

INTRODUCTION

Recently attention has been given to the development of mini-computers for on-line data analysis (see, for example, references 1 and 2). A particularly attractive use of these computers for this type of effort is in conjunction with an interactive graphics package consisting of a display scope, light pen, external program interrupt devices, and data input devices for data manipulation.

The advantage of using an interactive graphics package is twofold: (1) it gives the user a visual representation of the results at each step of the calculation and (2) it allows the user maximum on-line control over the direction in which the calculation proceeds and over the quality and accuracy of the calculated results. In general, interactive graphics can be adapted to any computer program where these advantages are desirable.

The purpose of this report is to describe how a computer code using interactive graphics may be used to perform reduction and processing of neutron spectrometry data. Included is an outline of the data analysis procedure and of the computer program written to perform this analysis. A listing of the main portion of this program is available from the author.

NEUTRON SPECTROMETRY DATA ANALYSIS PROCEDURE

The general procedure for neutron spectrometry utilizing liquid scintillation proton recoil detectors is fully discussed in references 3 and 4. The procedure in use at Lewis Research Center is briefly outlined below.

An NE213 liquid scintillation detector is used for neutron spectrum measurements. The active region of this detector is a nominal 1/2 by 1/2 inch cylinder. The linear output of the detector is sent to a preamplifier, amplifier, and into one side of a two-dimensional multichannel analyzer (see fig. 1). Another output (from the last photomultiplier dynode) is sent into a modified Owen pulse shape circuit (ref. 5). This circuit is necessary since both neutrons and gamma rays can initiate nuclear reactions in the detector: neutrons interacting by proton recoil and gamma rays by Compton scattering. This circuit distinguishes between the pulse shapes resulting from these two reactions. The output of this circuit is then directed to a preamplifier, amplifier, and into the other side of the multichannel analyzer.

Data is accumulated in the multichannel analyzer as a 64 by 64 channel matrix. Figure 2 shows a typical scope display of this data. The abscissa of this matrix is related to the energy of the particle initiating the nuclear reaction in the detector, the ordinate to the shape of the pulse (to distinguish gamma ray and neutron induced pulses), and the intensity of each point to the number of counts in that channel. Those channels which correspond to pulses initiated by neutrons and by gamma rays are indicated in figure 2. The 64 data values found in a typical column of the matrix are shown plotted to the left of the matrix. The upper peak due to neutrons and the lower peak due to gamma rays are usually easily distinguished.

It is normally desirable to collect data over a larger energy region than 64 channels of data can adequately cover. Hence data is taken at two or more gain settings, each of which provides 64 channels of data for overlapping energy regions.

The major steps in the analysis procedure are outlined in figure 3. For each column of data, as shown in figure 2, the minimum between the neutron and gamma ray peaks is calculated in order to separate gamma ray counts from neutron counts. The neutron counts are then summed for each column to obtain the proton recoil spectrum. This procedure is repeated for the data from all the different gain settings that were run. The next step in the analysis involves normalizing the individual proton recoil spectra for each gain to the same counting time and source strength. These spectra are then merged into a composite proton recoil spectrum. The final step involves analyzing the proton recoil spectrum to obtain the neutron spectrum. Numerous techniques exist for this latter step. The two major ones in use are unfolding the spectrum using a set of detector response functions (for example, see reference 6) and numerically differentiating the spectrum. For small detectors such as discussed here, the differentiation technique is much more convenient and accurate (ref. 4,7,8,9). It is this latter method that is adopted in the computer program discussed below.

DESCRIPTION OF COMPUTER PROGRAM AND INTERACTIVE GRAPHICS PACKAGE

The code which makes use of interactive graphics to perform the above analysis is called SOCONS (Symmetrical On-line Calculation of Neutron Spectra). SOCONS was written for a PDP-15/30 computer (see fig. 4), to which an X-Y display scope, a light pen, and a set of panel switches were interfaced (see fig. 5).

A program that takes advantage of interactive graphics techniques differs somewhat from the typical program that is run on larger computers. For example, the program is usually written as one large loop, perhaps containing several subloops. The purpose of this large loop is twofold: (1) the display can be updated by calculating or editing the displayed data, as desired, each time the program passes through the loop and (2) the status of certain external program interrupts and external data input devices can be sampled each time through the loop. Program interrupts serve the purpose of allowing decisions by the user at many locations throughout the program, while external data input devices are a convenient and rapid method of assigning new values to variables in the program. All the interrupts and input devices used here are controlled by assembly language subroutines which can be called by a Fortran program.

The display routines for SOCONS, all of which can be called from Fortran statements, run independently of the rest of the program. Displays are updated automatically as new data is calculated. In addition to graphical displays, alphanumeric data can also easily be plotted on the display screen by means of a Fortran WRITE statement.

The main routines in SOCONS are written entirely in Fortran IV. The code is divided into a main program for control purposes and nine subroutines to accomplish the several functions of the code (see table 1). The order in which these functions are performed is determined by the user by means of the light pen and display scope. The usual order is that shown in the table.

In order to establish the energy scale for which the data is taken, a Na-22 gamma ray source, having two well-known gamma ray energies, is used (subroutine CALIB). A typical Na-22 gamma ray calibration spectrum is shown in figure 6 (figs. 2 and 6 to 9 are taken directly from actual scope displays). Since gamma rays interact by Compton scattering in this detector, no photopeaks are seen. However, the Compton edges of the two gamma rays are easily observed. The user chooses the aporoximate maxima for the two Compton distributions with the light pen. Then the channels corresponding to the half-height of the Compton distribution for each gamma ray are determined to obtain a linear relationship between energy and channel number. The calibration data can be smoothed at any time during the analysis. The calibration can be repeated as many times as desired with different parameters until satisfactory results are obtained.

Raw data is received in the form of a 64 by 64 matrix displayed as a contour plot (see fig. 2). As mentioned before, the abscissa is related to the energy of the particle initiating the nuclear reaction in the detector, the ordinate to the shape of the pulse (to distinguish gamma ray and neutron induced pulses), and the intensity to the number of counts in that channel. The upper group of high intensity points in figure 2 indicates neutron-induced counts, while the lower set results from gamma rays. The vertical and horizontal displays to the left and bottom of the contour plot correspond to the column and row of the last point of the contour plot seen by the light pen.

The first step in the calculation of the proton recoil spectrum for the particular gain setting being considered is performed analytically by locating the minimum between the gamma ray peak and the neutron peak in each column of data (subroutine MNCLC). The purpose of this calculation is to separate the neutron induced counts from those initiated by gamma rays. Sometimes a false minimum is calculated due to poor counting statistics or poor resolution between the two peaks. In this event, the user has the option of editing this data, which is displayed on the scope, with the aid of the light pen to achieve more satisfactory results. The proton recoil spectrum for the gain setting being considered is then determined by the sum of the counts in the neutron peak. In order to minimize the effects of poor counting statistics, the spectrum can be smoothed any desired number of times, including none (subroutine ESMTH). The smoothing is done by a five-point quadratic least squares fit to the data.

SOCONS presently handles data from only two gain settings. Once a proton recoil spectrum has been determined for each of the two different gains (see fig. 7), the user can normalize these two sets of data to the same counting time and source strength (subroutines RATIO and NRMLZ). The user accomplishes this by inputting a suitable normalization factor on one of the external data input devices. As this is done, the displayed points of the higher energy set of data move vertically by that factor. For any given factor, the standard deviation between the high and low gain data is calculated for the overlapping energy region to provide a degree of fit parameter. After an acceptable factor is found, the data can then be merged into a single proton recoil spectrum (see fig. 8).

The normalized proton recoil spectrum is next interpolated at a predetermined set of neutron energies (subroutine INTRP), namely those used by the unfolding code FERDOR (ref. 6). The interpolation is performed by a double three-point Lagrangian interpolation scheme (ref. 10). Up to this point in the calculation, the analytical procedure involved has been patterned after the code PREJUD (ref. 11), which performs a similar analysis, but without the interactive graphics. These procedures are applicable to all sizes of NE213 detectors. Two options exist at this stage: (1) the proton recoil spectrum can be punched out and used as input to FERDOR (ref. 6) or TUNS (ref. 8), or (2) the calculation can proceed on-line to the next step, which is described in the next paragraph.

The last major step in the analysis (subroutine DERIV), which pertains only to a 1/2 by 1/2 inch NE213 detector, involves the numerical differentiation of the proton recoil spectrum to determine the neutron spectrum which was incident upon the detector (see fig. 9). The theory behind determining neutron spectra in this manner is given in reference 7, and an application to proton recoil detectors is given in reference 4. The numerical technique used is a double three-point Lagrangian differentiation (ref. 10). The differentiation section of SOCONS was patterned after the calculational procedure of the code TUNS (ref. 8). The calculated neutron spectrum can be printed out on the teletype, punched onto paper tape, or stored on DECtape.

In addition to the procedures listed above, subroutine USMTH can be used at the appropriate time to smooth the normalized and interpolated proton recoil spectra, as well as the final neutron spectrum.

CONCLUDING REMARKS

Determination of neutron spectra by the method described above takes of the order of thirty minutes, which includes time for decisions by the user. Typically a longer time is required before results are actually <u>in hand</u> for the same analysis performed on a larger computer without interactive graphics features.

A particular advantage of SOCONS is the freedom from using paper tape and IBM cards for data and from the bothersome and time-consuming chore of plotting data by hand.

Perhaps the main advantage of a computer program using interactive graphics is that the user generally ends up with satisfactory results because of the program interaction. This, of course, avoids the problem of having to resubmit data with new input parameters until proper results are obtained. In addition, even if results are not as good as desired, because of having followed the calculation and having seen a visual display at each step, the user has an understanding of where the calculation went amiss.

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TABLE 1. SOCONS ROUTINES AND INTERACTIVE OPTIONS

Routine	Option
SOCONS	Choose next subroutine
IDATA	Control data input/output devices Select slices of contour plot to be displayed
CALIB	Choose maxima of Compton distribution to calculate half-height channels Smooth calibration data
MNCLC	Edit calculated values of minima
ESMTH	Smooth proton recoil spectrum Eliminate channels with invalid data
RATIO	Eliminate channels with invalid data
NRMLZ	Eliminate channels with invalid data Enter normalization factor Merge proton recoil spectra
USMTH	Smooth proton recoil and neutron spectra Eliminate channels with invalid data
INTRP	
DERIV	

Note: For all of the main calculational subroutines used in SOCONS, there are also options to print or punch out data, as desired, as well as to change the scale and multiplication factors of the displayed data.

FIGURE CAPTIONS

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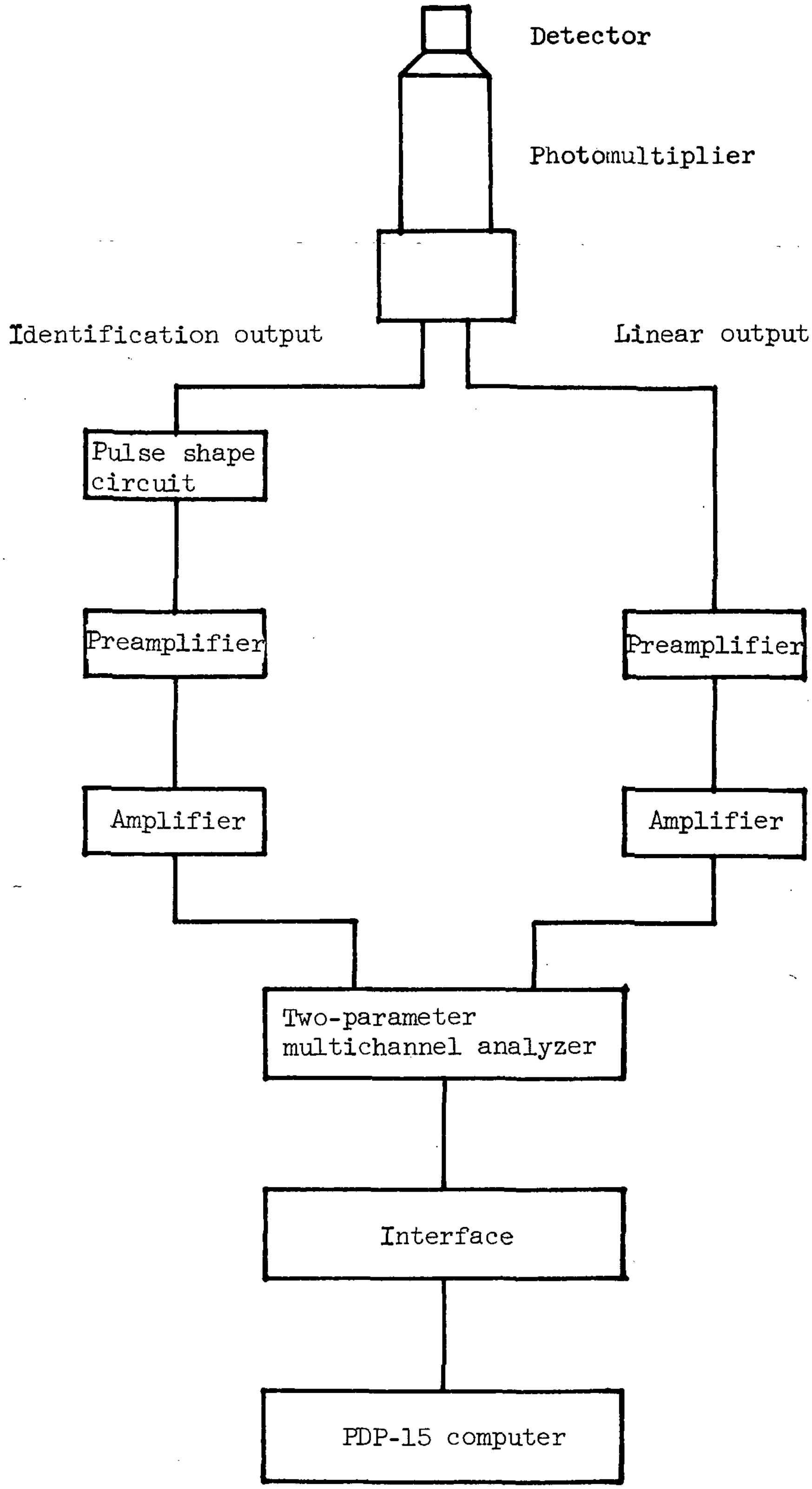

Figure 1. Detector system

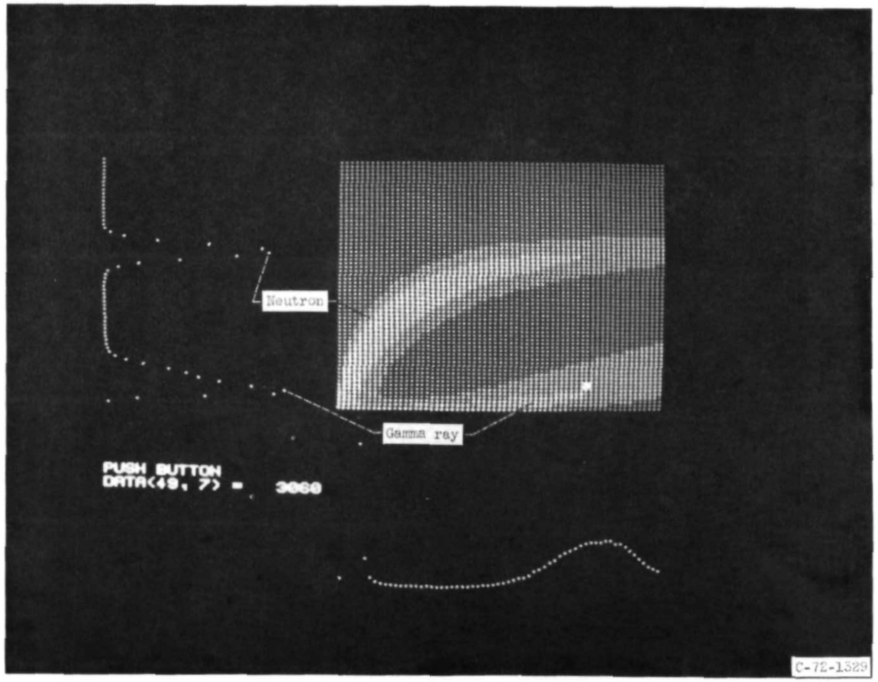

Figure 2

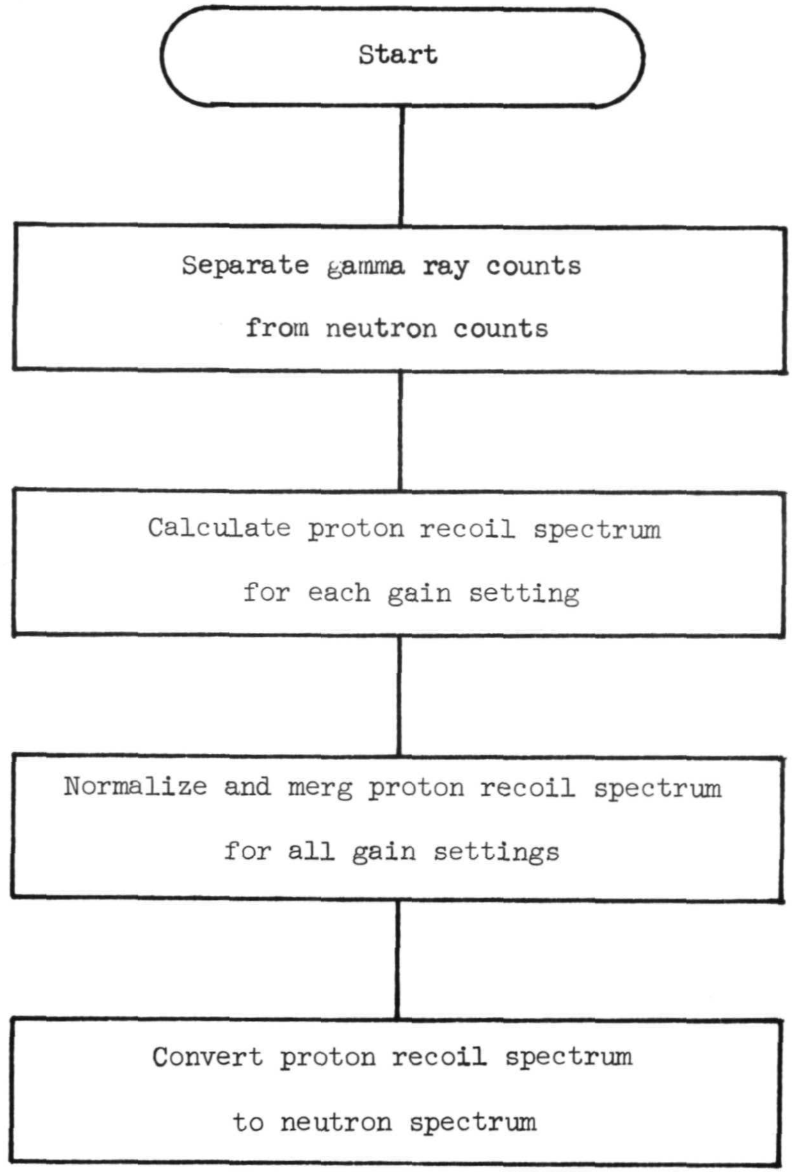

Figure 3. Calculational flow chart

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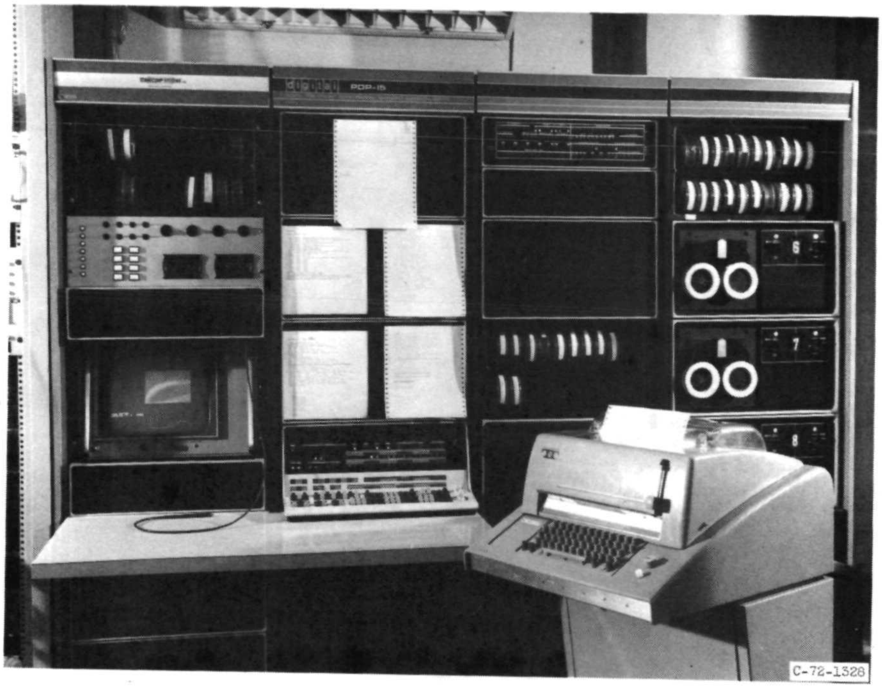

Figure 4

Figure 5

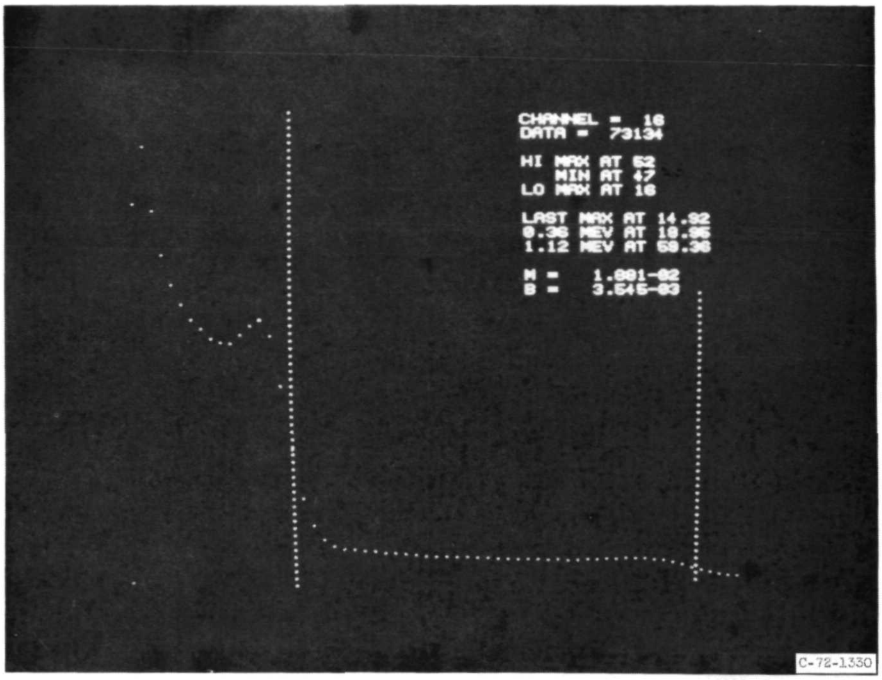

Figure 6

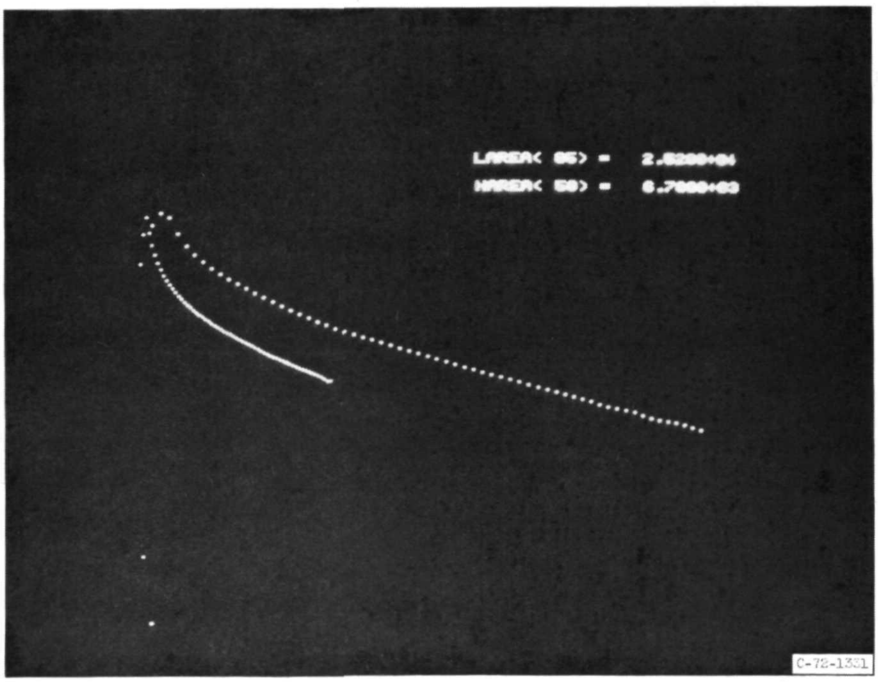

Figure 7

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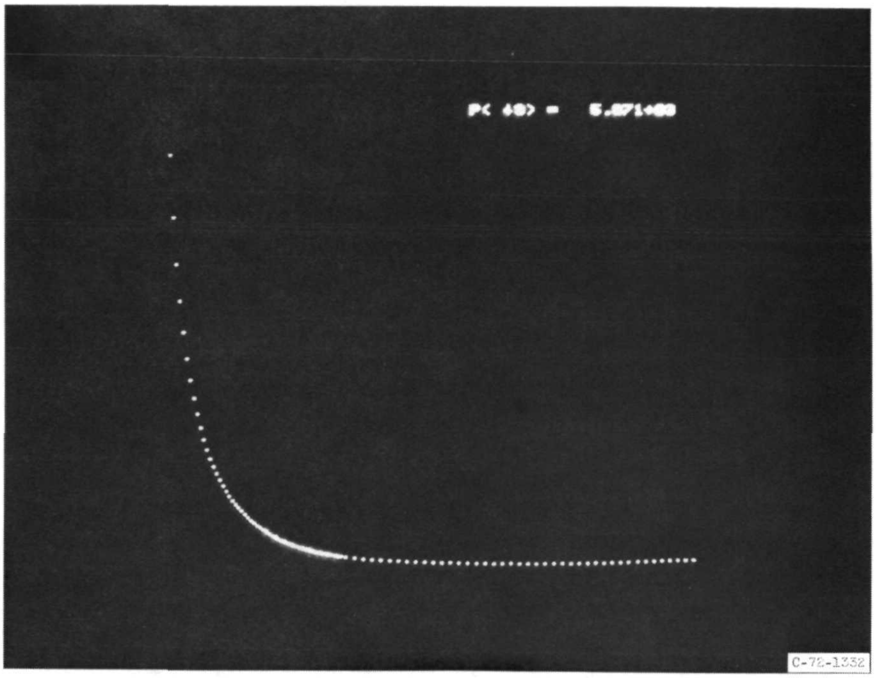

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Figure 8

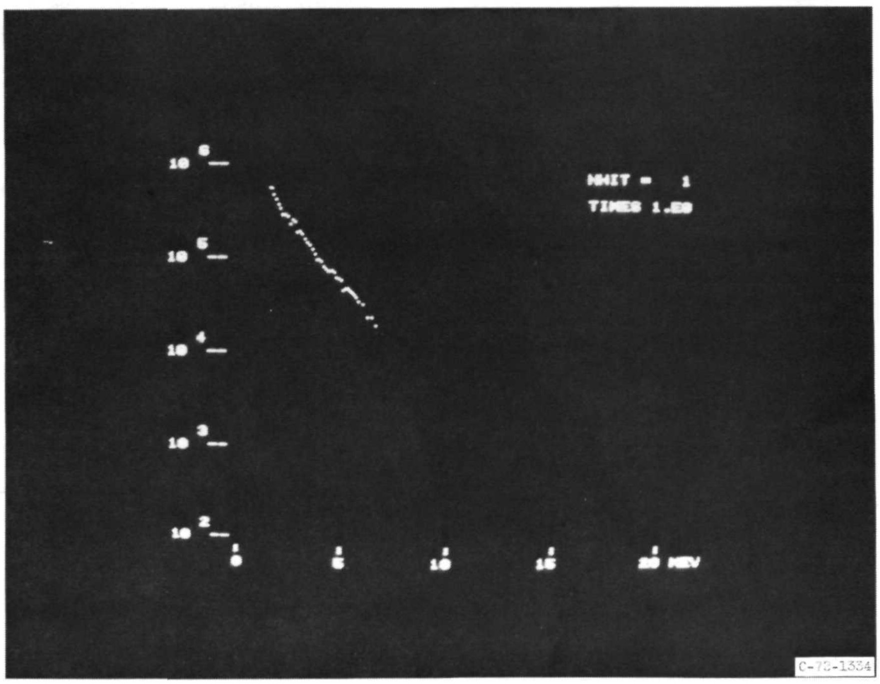

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Figure 9